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NAVY DEPARTMENT

Report On

An Analysis

of

The Anti-Submarine Warfare Problem

from the Standpoint

of

Underwater Acoustics

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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From: Director, Naval Research Laboratory
To: Commander-in-Chief (Readiness)

Via: (1) Bureau of Ships
(2) Bureau of Aeronautics

Subject: Underwater Sound - Analysis of the Anti-Submarine Warfare Problem from the Standpoint of Underwater Acoustics - Report No. 1908 prepared by Dr. H. C. Hayes of Naval Research Laboratory, Anacostia Station, Washington, D. C.

Reference:
(a) NRL ltr. C-A16-3(21) of 22 Dec. 1941 to Opnav (Fleet Training), via BuShips; copies BuOrd, CR&D, Opnav (DNC).
(b) NRL ltr. C-A16-3(21) of June 9, 1942, to BuShips, copies to Cominch (Readiness), Opnav, A/S Warfare Unit, CO Fleet Sound School Key West, CO Fleet Sound School San Diego, CR&D.
(c) NRL ltr. C-A16-3(21) of June 24, 1942, to BuShips, copies to approx. 40 information addressees.
(d) NRL Report S-1776 of 27 August 1941.

Enclosure: (A) Three (3) copies of Report No. 1908 prepared by Dr. H. C. Hayes and dated July 17, 1942.

1. Enclosure (A) is forwarded herewith for consideration and comment.

2. The enclosure is a treatise covering certain major features of underwater acoustics as applicable to the current anti-submarine campaign. Closely associated with the references, it is the result of long observation and painstaking efforts by Dr. Hayes, Superintendent of the Sound Division, who has been actively engaged in a study of anti-submarine methods (see reference (a)). Some of the points raised in enclosure (A) -- such as the employment of patrol aircraft, blimps, and gliders carrying underwater sound apparatus -- may prove to be controversial; however, in view of the long experience of the Laboratory's Sound Division in underwater acoustics, it is felt

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that all the suggestions brought forth should receive attention, particularly since the submarine menace is so acute. Applications of the tilting beam projector and the associated Direct Attack Method are fully covered in references (b) and (c).

3. It is suggested that the enclosure may be of such interest and importance as to warrant a conference for discussion of its chief points.

H. G. Bowen

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(each with 1 copy of Enc. (A))

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ABSTRACT

The purpose of this report is to direct toward better effectiveness our efforts to control the U-boat menace. To this end it points out the weaknesses inherent in the indirect attack procedure and, in the light of an analytical study of the present situation, depicts the nature and scope of, and outlines the requirements for a solution of the anti-submarine problem.

This study leads to the conclusion that the problem can be solved, and the U-boat menace greatly reduced, (a) by equipping the blimps and planes of the aircraft patrol with underwater sound detectors by which they can direct patrol ships to more frequent sound contacts with the target, and (b) by increasing the percent of attacks that result in kills by discarding the present indirect attack procedure in favor of the Direct Attack.

The Direct Attack procedure involves running directly over the submarine and at this instant as shown on a depth recorder, dropping a pattern of rapid sinking, contact or proximity depth charges.

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I. INTRODUCTION

1. Control of the U-boat menace, particularly as regards our far-flung coastwise shipping, is admittedly ineffective. Of the efforts calculated to improve the situation, a considerable portion has been spent in the development of non-essentials due to lack of a clear understanding of the anti-submarine problem as a whole. The following analysis depicts the problem as conceived by the Sound Division, states the requirements for its solution, and outlines the status of the Laboratory's developmental program for fulfilling these requirements.

2. Experience in this war shows that a major portion of the sinking and damaging of U-boats has been accomplished by depth charge attacks directed by sound detecting equipment on patrol ships, and there is no convincing reason for believing that this condition will not continue for some time to come. Thus, the sound equipped patrol ship must be regarded as the most effective weapon as yet developed for combating the submarine, and thus far the only weapon that can carry the attack to a submarine operating submerged.

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3. The effectiveness of the patrol ship is measured by the product of two factors of which one (a) is the frequency of sound contact with the U-boats, and the other (b) is the percent of contacts that result in kills. It may be noted that the magnitude of the second factor is determined wholly by the ship itself, since it depends on the design of the ship, the capabilities of its sound and radar detection equipment, the character of and means for launching its depth bombs, and the training and experience of its personnel. It will be seen that the value of the first factor is determined, to a large extent, by other and outside agencies.

II. FREQUENCY OF CONTACT

A. Making Contact

4. Considering the first factor, it may be stated that the limited range and operating speed of underwater sound detectors makes them inefficient for hunting submerged submarines over such wide areas as obtain along our extended coast lines. Therefore, our patrol ships even when their numbers have been considerably increased, cannot be expected to make frequent sound contact with the U-boats that are preying on our coastwise shipping, unless they are definitely directed to such contacts by means other than their own sound equipment.

5. The use of radar on these ships often will direct them to sound contacts that otherwise would be missed, particularly during the night and other periods of low visibility, but even so the patrol ship is still an inefficient means of hunting submarines due to its speed limitations, the relatively short range of its radar, and to the fact that the radar may serve to give a surfaced submarine advance notice of the patrol ship's presence so that it can submerge well beyond sound range, -- in which case its chances of escape are highly favorable.

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6. Such reasoning leads to the conclusion that the sound and radar equipped patrol ship alone is inherently an inefficient means of controlling the U-boat menace since its low search rate can provide only a low frequency of contact with these boats. This frequency of contact factor naturally increases as the operating area of the submarine is defined and limited. As a result, the efficiency of the patrol ship reaches a maximum when the ship is employed to protect a convoy and a minimum when shipping is scattered at random over long and wide traffic lanes.

7. While the patrol ship alone cannot, because of its inherently low frequency-of-contact factor, control the U-boat menace there is reason to hope that, so far as this factor is concerned, it can be made a powerful means of such control through cooperation with the aircraft patrol. This hope lies in the possibility of satisfactorily equipping our patrol planes and blimps with means for definitely directing a patrol ship to sound contact with a submerged submarine. If the patrol ships could contact but a fractional part of the U-boats that the aircraft patrol overtakes and forces to submerge, the submarine warfare along our coast would become unprofitable to the enemy.

8. The need for such a means has been recognized, and numerous suggestions have been made involving expendable buoys that carry a submarine microphone, and magnetic detectors of various types. Development of devices of both types is under way. However, there is reason for believing that none of these devices can adequately serve the subject purpose.

9. Magnetic detectors mounted on planes should not be expected to detect a submerged submarine at ranges much greater than its length (roughly 300 feet), and since the plane must fly at some height above the water, and since all modern submarines can safely submerge to at least 300 feet, there is reason to believe that the plane not only cannot hold magnetic contact with a submarine that it has forced to submerge until a patrol ship arrives, but that it cannot detect the submarine at all if the submarine so wills. But even if the detection sensitivity could be raised to the point where passage across the target would give a clear signature, it appears doubtful that the plane could follow the movements of the target because of the very limited width of the path it can sweep magnetically.

10. The sound detecting expendable buoy (radio, or other type) can operate on a submerged submarine to an acoustic range varying from 1 to 3 miles depending on sea conditions. An average of something like 2 miles may perhaps be expected. The escaping submerged target can make at least 8 knots and should not be expected to make less than half speed. Thus, sound contact with the target should not average more than thirty minutes. Since the direction of the target is wholly unknown, the chances of regaining sound contact by dropping more buoys are so slight that the number of buoys required to assure such contact while a patrol ship proceeds to the attack from a range of say 60 to 75 miles, is impractical if not prohibitive. Therefore, about the only information the plane can give the arriving patrol ship through the use of expendable buoys is that the buoy marks the approximate location of a U-boat at the time the plane radioed the ship some (T) hours ago.

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11. Meantime, the potential operating area of the submarine, which the arriving patrol ship must sweep to gain sound contact, will approximate the area of a circle having a radius equal to the distance the submarine at speed of S_s can run during the time elapsed after it submerges. The area in square miles swept by the patrol ship at any time (t) hours after arriving at the marker buoy will equal the product of its speed in knots (S_d), twice the athwart ship range (W) of its sound detectors, and the time (t). The escaping chances of the target at any time will equal its potential operating area divided by the area swept by the patrol ship. Calling this quotient C, the potential operating area A and the swept area a, then, -

$$C = \frac{A}{a} = \frac{\pi S_s^2 \, (T + t)^2}{2 \, W \, S_d \, t} \quad \text{where}$$

$$A = \pi S_s^2 \, (T + t)^2 \text{ and}$$

$$a = 2 \, W S_d t.$$

Inserting the practical values,

$$S_d = 20 \text{ knots} \qquad T = 2 \text{ hrs.}$$

$$S_s = 6 \text{ knots} \qquad t = 1 \text{ hr.}$$

$$W = 3000 \text{ yards}$$

$$2W = 6000 \text{ yards} = 3 \text{ nautical miles}$$

then,

$$C = \frac{\pi 6^2 \, (2 + 1)^2}{3 \times 20 \times 1} = 17.$$

Thus, the chances are 17 to 1 that the target will escape a search of one hour by the patrol ship. The effect on the chances of escape of continuing the search can be understood by differentiating C with respect to (t).

$$\frac{dC}{dt} = \frac{d}{dt}\left(\frac{\pi S_s^2 \, (T + t)^2}{2 \, W \, S_d t}\right) = \frac{\pi S_s^2}{2 \, W \, S_d}\left[1 - \frac{T}{t}\right]^2$$

And since this becomes zero when the search period (t) equals the time (T) required for the patrol ship to reach the marker buoy, the submarine's chances of escape will be a minimum, if, in our example, the search time (t) equals 2 hours. Under these conditions the chance of escape drops to the minimum value of 15 to 1. Considering the inaccuracies of sweeping courses, the time consumed in turning, etc., it appears that these calculated chances might well be doubled.

12. The marker buoy dropped by aircraft can serve as a point of departure for search when a patrol ship arrives. This should lead to some increase in the frequency of sound contact despite the fact that the

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chances of escape definitely favor the submarine. The use of such buoys on patrol planes and blimps is recommended at least as a temporary measure. The inclusion of sound reception and radio transmission in such buoys adds little or nothing to their usefulness as markers. They should be designed for clear visibility in daylight and should carry a flare for use at night.

B. Maintaining Contact

13. The frequency with which our patrol ships contact the U-boats oannot be raised to the point required for controlling their operation through the use of magnetic detectors mounted on aircraft or of expendable buoys dropped from such craft. But there is reason to believe that it could be raised to such a point if the patrol planes and blimps could be equipped with directive underwater sound detectors by which they could follow the target until a patrol ship arrived. The development of sound detectors designed to serve this purpose has been undertaken by the Naval Research Laboratory and experimental models are nearing completion. They should be ready for test on or before August 1942.

14. Since the slowest flight-speed of a patrol plane is well beyond the maximum for trolled devices, it can operate underwater sound equipment only when the surface conditions permit landing. While such conditions obtain but a small percent of the time, this unfavorable factor is somewhat offset by the fact that the listening conditions on a surfaced plane should prove favorable, due to the fact that a plane's propeller sounds scarcely penetrate the water, and to the fact that U-boats are especially active during such favorable surface conditions. Moreover, it seems probable that a patrol plane could be built to land safely under considerably less favorable conditions than present designs permit. It also seems possible that a glider, consisting of a light, rugged boat or pontoon, with folding or expendable wings and equipped with underwater sound detectors and a small outboard motor for propulsion could be towed by the patrol plane. This glider would serve the subject purpose even better than the plane and under less favorable sea conditions because, when cut loose, it could land at slow speed. Obviously, the patrol plane would afford protection to the pontoon and its two operators until the patrol ship arrived and hoisted it aboard either before or after attacking the target.

15. A simple tilting beam type of directive sound detector suitable for use on a surfaced patrol plane or glider has been developed to the point where its possibilities have been tested on a motor sailer. The results were so favorable that the device is being put into final form for installation and tests on a patrol plane. This receiver is designed to project through the bottom of the hull and will require a stand pipe or well 8" I.D. that extends upward above the water line. The receiver, in its lowered position, extends 2' below the bottom of the well and houses in the well when raised. When not in use the receiver can be withdrawn and stowed and the well top closed with a screw-cap. The weight of the receiver and its amplifier approximates 50 pounds. The total weight including the stand pipe should not exceed 70 pounds.

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16. Of the reasons advanced against the proposed operations of patrol planes, two which involve the safety of the plane, merit consideration. The first states that the patrol plane is not designed or intended to alight at sea except in case of emergency. The answer is that this fact is fully recognized. It is admitted that present designs of patrol planes require uncommonly favorable surface conditions to take off again after having landed. Such conditions, however, often exist along our Atlantic coast, particularly during the Summer and early Fall months when the U-boats are most active. The patrol planes could serve the subject purpose with impunity during such periods. It is submitted, however, that the U-boat menace may reach a stage - if it has not already done so - where the question of safety, except for the personnel involved, must become secondary if the destruction of the submarine is to be assured.

17. The second reason questions the ability of the surfaced plane to avoid destruction by gun fire in case the submarine suddenly emerges. The answer is that complete protection against such an emergency can be afforded if the patrol planes operate in pairs, one remaining poised for making a bomb attack if the target surfaces. This procedure calls for no sacrifice of the patrol area, since the two planes can proceed roughly abreast on parallel courses separated by a considerable distance if desired. It offers the advantage that full cooperation between patrol planes and patrol ships can be effected by equipping only half of the planes with an underwater sound detector.

18. Moreover, because the surfaced plane generates very little underwater sound to disclose its presence to the submerged target, there is reason to believe that the target will often surface before a patrol ship arrives and thereby expose itself to bomb attack. Such cooperative tactics by the patrol planes should account for a few U-boats at the outset, should later prove effective in curtailing their operations by keeping them submerged (since it would become hazardous for any submarine to surface after it had been forced to submerge by a patrol plane), and finally should tend strongly to undermine the morale of the U-boat personnel.

19. The blimb can often fly at speeds and altitudes within the operating range of towed underwater sound receivers, and hence should be able to use such devices to maintain sound contact with a submerged U-boat until the patrol ship arrives. The development of a simple device to serve this purpose is underway at this Laboratory.

20. The device consists of a beam-type underwater sound projector mounted in a streamlined form that tows from the blimp by a 500 foot cable enclosing 2 shielded conductors and a small steel or bronze tension member. The projector is designed for both direct and echo sound detection in two bands centered at 17.5 and 35 kc. These provide respectively a wide beam for search and a narrower beam for tracking the target. The total weight of the equipment will approximate 300 lbs. and the power requirements, when used for echo detection will average about 300 watts. The equipment should be ready for preliminary tests by the middle of August.

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21. While the blimp cannot sweep as much area as the patrol plane, it can, by virtue of its ability to operate under less favorable sea conditions, probably play a more important part in the subject cooperative program than can the present designs of patrol planes. There is a possibility, therefore, of strengthening this branch of the aircraft patrol and of equipping each unit with a suitable towed directive sound detector, when it has been proved experimentally that the proposed system is feasible.

22. Vulnerability of the blimp to submarine gun fire appears not to worry lighter-than-air personnel, yet it seems reasonable to believe that, when the U-boat captain fully realizes that the blimp can place a patrol ship within echo range of his ship, he may prefer a gun fight with the blimp to waiting for a depth bomb attack by a patrol ship. Such a procedure on the part of the target can and should be forestalled by cooperative effort between the blimp and the patrol plane.

C. Cooperative Patrol Program

23. A consideration of ways and means of bringing the patrol ship into sound contact with the U-boats operating along our coast leads to the conclusion that the blimp may well be regarded primarily as a connecting link between the patrol ship and the patrol plane. If it can hold sound contact with a submerged target under sea conditions that prohibit the plane from landing and can reach the plane's marker buoy in time to favor contacting the target, one of its functions -- possibily its main function -- should be to respond with all speed to calls from the patrol planes, make sound contact with the target, and hold that contact while the plane continues to patrol from the air and the patrol ship steams to the attack. When the patrolling blimp discovers a U-boat, a sane procedure would be to call both patrol plane and ship and still act as an intermediary by holding sound contact while the ship approaches and the plane keeps alert for an air attack.

24. The above considerations lead to the conclusion that the "frequency-of-sound contact" factor could be greatly improved if we can provide our patrol planes and blimps with underwater sound detectors and institute a cooperative patrol program aimed toward directing our patrol ships into sound contact with the U-boats that the aircraft have overtaken and forced to submerge.

III. PERCENTAGE OF KILLS

25. It remains to consider the factor determined by the percent of such sound contacts that result in kills. This percent, as stated in paragraph 3, depends on:

(a) The design of the patrol ship,
(b) The capabilities of its sound detection equipment,
(c) The character of and means for launching its depth bombs,
(d) The training and experience of its personnel, and
(e) The tactics employed in making an attack.

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The effectiveness of the anti-submarine attack is obviously a function of all these factors, none of which is wholly independent of the others. Hence, their relative importance cannot be wholly determined by considering each one separately.

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A. Patrol Boat Design and Equipment

26. Regarding the patrol ship itself- which preferably would be termed an anti-submarine ship - its design should be such as to permit carrying out to best advantage its main mission, which is to combat submerged submarines with sound-directed depth-bomb attacks. This postulates a design that permits the sound equipment to function at full capability.

27. Development of the underwater sound detector, at least as regards range and directivity, may be regarded as having reached practical limits. Its anti-submarine effectiveness, however, can be markedly improved by supporting the projector on gimbals in a streamlined structure extending about 20 feet below the water line and located at or near the turning axis of the ship. This calls for a ship with a streamlined keel about 6' deep, within which a retractable dome shield can be mounted.

28. The advantage afforded by such a keel mount should prove about equally effective for all types of underwater sound detectors. These advantages are as follows:

(a) The projector is far enough astern to escape the strong churning motion due to pitch, and the attendant background of noise and quenching by entrapped air bubbles. This mount would leave the projector in an acoustically clear medium at all times while the present destroyer mount, when the ship pitches, provides sound-clear water only during the lower portion of the dip. Under the rough conditions that prevail in the North Atlantic the projector is either in the air or quenched in air bubbles about 50% of the time. Moreover, this produces a situation even more unfavorable than appears from this figure by leaving the acoustically clear periods too short to transmit a signal and receive its echo before quenching occurs.

(b) The projector is below the turbulent and air laden water adjacent to the hull even though it is located well back from the bow.

(c) The deep keel will dampen and increase the period of roll and thus tend to steady the sound beam.

(d) The axis of the sound beam normally sweeps out a horizontal plane when the projector is rotated and the ship is on even keel. Therefore, when the ship rolls or pitches, it executes angular harmonic motion in a vertical plane and passes through the horizontal plane when its angular velocity is a maximum. It follows that the sound beam can

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contact the target but a small percent of the time whenever the ship rolls through an angle greater than the angular spread of the sound beam, which, at a range of 1000 yards, averages about 10 degrees. Echo detection at such times is difficult and must be confined to ranges where the time interval between signal and echo is less than 1/2 the rolling period of the ship. The gimbal mount will tend to counteract the undesirable tilting of the sound beam normally produced by both roll and pitch of the ship. This will serve to keep the sound beam directed horizontally and thereby make it potentially available for search or attack during a larger portion of the time, particularly under rough surface conditions.

29. Such considerations backed by practical experience warrant the assertion that the effectiveness of the underwater sound detector will prove greatly superior to that given by present performance if or when a ship is forthcoming that provides for mounting the projector as above briefly described. For some 20 years this "painted ship" has lain becalmed on "a painted ocean" awaiting a favoring breeze.

B. Present Attack Procedure

30. An estimate of the relative importance of the remaining factors entering into the present anti-submarine attack, as set forth in this Laboratory's Report No. S-1776, leads to the conclusion that the present procedure, which was developed a full generation ago to utilize to best advantage the sound equipment of that day and age, must be modified or replaced by a new attack procedure that will employ to best advantage the equipment of today. A consideration of the weaknesses of the present indirect attack procedure and the full capabilities of modern sound detecting equipment leads logically to the conclusion that the attack approach should be directed at the target and not at a fictitious point on its projected course. A discussion of such considerations follows.

31. The low percentage of kills under present attack procedure is due to the relatively long time interval it provides the submarine for employing escape tactics. In other words, it affords the target a potential escape volume that is far greater than can be covered by a depth-charge pattern. Therefore, the new attack procedure must be directed primarily toward reducing the target's potential escape volume to a minimum, and this calls for a procedure that reduces the escape time interval to a minimum.

32. The escape interval starts at the instant the ship leaves the point of departure for the attack and therefore at the instant it squares away on the attack course. It ends when the depth charges reach the level of the target. This total interval analyzes into the sum of two intervals t_1 and t_2, wherein t_1 represents the time consumed in steaming from the point of departure to the point of attack, and t_2 represents the time interval between initiating the depth charge pattern and the arrival of the charges at the level of the target. Therefore, the new attack procedure must aim to reduce each of these two intervals to a practical minimum.

33. The interval t_1 can be shortened by increasing the attack speed of the destroyer, by reducing the distance between the point of departure and the point of attack, or by both. It becomes an absolute minimum of value zero when these two points coincide, irrespective of the speed of the destroyer. If such a minimum can be employed practically the potential operating volume of the target will be wholly determined by t_2, the time required for the bombs to sink to the target. Raising the bomb speed to practical limits then becomes of prime importance.

C. The Direct Attack

34. Our new attack, properly termed "The Direct Attack", aims to eliminate the time interval t_1 by directing the approach at and across the target by echo reception on a measurably controlled tilting projector, and by laying a pattern of high speed contact or proximity fused bombs about a point vertically over the target as disclosed by target echoes when the projector is trained vertically downward. Passage over the target also may be indicated by the chemical recorder and possibly by magnetic detection. The percent of attacks that result in kills under such a procedure should approximate 100 when the ratio of bomb pattern and potential escape areas exceeds unity and drop to lower values as this ratio becomes less than unity.

35. The potential escape area of the target approximates a circle of radius R_o equal to the distance the target runs while the bomb falls a distance H to its level. It follows that,

$$R_o = \frac{H}{S_b} S_s$$

where S_b and S_s represent respectively the speed of the bomb and the speed of the target. Thus the potential escape area A_o of the target becomes

$$A_o = \pi \left(\frac{H}{S_b} S_s \right)^2$$

A practical limit for the radius R_b of the bomb pattern, as averaged from individual estimates, is about 72 ft. and the area A_b of the bomb pattern becomes $A_b = \pi R_b^2$. The ratio of the two areas A_b/A_o thus becomes

$$\frac{A_b}{A_o} = \frac{\pi R_b^2}{\pi \left(\frac{H}{S_b} S_s \right)^2}$$

and the proportion of sound contacts that result in kills in largely determined by the value of this ratio.

36. The magnitude of factors H and S_s are set by the tactics of the target, and control over them is limited to our ability to influence those tactics. The Direct Attack aims to exert such influence through restriction of time. And although British reports estimate the maximum value of H and S_s for the modern U-boat to be 600' and 8 knots respectively, this attack procedure carried out at high speed should prevent the target from attaining these limits even if considerations of safety and battery conservation should not work to preclude them. Therefore, reasonable values for these factors would seem to be 240 ft. for H, and 6 knots, or 10 ft. per second for S_s. The velocity S_b of the depth bomb can be set by its design to approximate 40 ft. per second.

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37. Thus, the ratio of bomb pattern area A_b to the potential escape area A_o of the target for an estimated normal and practical attack becomes:

$$\frac{A_b}{A_o} = \frac{(72)^2}{\left(\frac{240 \times 10}{40}\right)^2} = 1.44$$

Since this ratio exceeds unity by a relatively large margin, it follows that The Direct Attack should prove 100% successful for somewhat larger values of H and S_s than those chosen to represent the average, and should give a high expectation of success even if the target manages to maneuver to the maximum limits of these factors.

D. Bombs

38. A discussion of the form and content of a bomb pattern best suited for the subject purpose involves numerous factors including means for projecting the bombs and therefore will not be undertaken here. It may be noted, however, that the pattern should satisfy three conditions:

(a) The bombs should be projected simultaneously by remote control from the bridge.

(b) The bomb pattern should be definitely centered about or positioned with respect to the sound projector, since no other point on the ship is known to be vertically over the target.

(c) A small contact or proximity fuse type of bomb must be used to avoid damaging the patrol ship.

It may also be noted that a single line of bombs becomes an effective pattern if it can be laid across the target far enough forward to prevent the submarine from escaping by passing underneath. The target normally requires about 30 seconds to run its own length of 300', and the bomb requires about 6 seconds to fall 240'. Thus, there is reason to believe that the simple hand laid line pattern may be used to advantage until projecting means are provided. So much for the conception and aims of the Direct Attack procedure.

39. The requirements of the Direct Attack procedure in materiel and in personnel training as compared with the demands of the present Indirect Attack Procedure will now be considered in turn.

E. Materiel Requirements for Direct Attack

40. The materiel required to execute the Direct Attack is as follows:

(a) Underwater sound equipment consisting of a driver, receiver-amplifier, range indicator or recorder, and a cooperating transceiver (projector) that can be measurably

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tilted between the horizontal and vertically downward directions, that can detect a submerged submarine to practical ranges, and that can determine its bearing to within $\pm 2°$.

(b) High speed streamlined bombs that follow a consistent trajectory at the highest practical terminal velocity, that carry a charge approximately 30 lbs. of T.N.T. and a contact or close proximity fuse.

(c) Means for projecting such bombs by remote control, from the bridge, or other prescribed location, at a speed at least equal to their terminal velocity.

41. This brief list completely covers the requirements - the necessities - for carrying out the Direct Attack. The present standard QC (magnetostriction) and the QB, (Rochelle salt) sound equipments lack only the tilting beam feature of meeting all requirements as regards both range and directivity, and the development of this feature has been completed by the Naval Research Laboratory. Thus, so far as detecting and directive sound equipment is concerned, all the necessities for executing the Direct Attack are at hand. Other developments either completed or under way, such as Lobe Reception, Echometer, Echo Vision, the latter of which is nearing completion at this Laboratory, must be classed as conveniences or refinements, and their perfection and adoption should not be expected to effect any marked improvement in our anti-submarine warfare.

42. The list also contains no aids for directing the attack such as the Attack Meter, and various designs of Plan Position Indicators, which though possible improvements for the Indirect Attack, are not essential for the Direct Attack.

43. While preliminary tests have proved the need for the tilting projector in properly executing the Direct Attack, they have also indicated that this procedure can be carried out with a fair measure of success with the present dome-shielded equipment by approaching at high speed and using the standard depth finder or chemical recorder to disclose the instant of crossing over the target. Loss of sound contact across the so-called "blind spot", or last 200 yards of the approach , will decrease the certainty of crossing the target, but the resulting accuracy of placing the bomb pattern may still make the direct procedure more effective than the present indirect procedure.

44. Thus it appears that, so far as materiel is concerned, the Direct Attack can be instituted whenever the high-speed bombs and projecting equipment are forthcoming. Moreover, preliminary tests using small projectiles indicate that (as a stop gap) the bombs can be launched by hand until projecting means are provided. Thus attention is again called to the immediate need for high-speed contact or proximity fused bombs.

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F. Personnel Training Requirements for Direct Attack

45. A comparison of the training and experience required for executing the Indirect and Direct Attack procedures can be best made by considering their respective tactics. Such a comparison follows. It will be seen to favor the Direct Attack.

46. The Indirect Attack procedure calls first for a determination of the course and speed of the target. These data, together with the estimated time of fall of the depth charge, serve to locate the center of the depth charge pattern along the projected course of the target. Since this point is well forward of the target, both course and speed must be known with a fair degree of accuracy to avoid excessive terminal error. This calls for accurate range and bearing data on the part of the listener, and a hurried use of such data by plotting or otherwise on the part of the navigator or conning officer.

47. The Direct Attack centers the bomb pattern about a point that is located directly by the sound equipment. It therefore calls for no computation on the part of the conning officer - a welcome relief during a period fraught with tension and excitement - and it requires less hurry on the part of the listener since his period of observation is not curtailed by the "blind spot".

48. The Indirect Attack next requires the navigator or conning officer to lay a course through the computed location of the depth charge pattern and to direct his ship along this course at a speed that will permit laying the bomb pattern at the proper time. Since the distance to the firing point is relatively short, this course must be directed along a tangent of the ship's turning circle. The common practice of laying the attack course in accordance with the straight line between the point of departure and the point of attack gives strong evidence of the need for a simplified attack procedure.

49. The Direct Attack here again relieves the conning officer or navigator by requiring him only to direct his ship to contact with the target and by supplying him during this maneuver with a continuous record of the target's bearing.

50. Finally the Indirect Attack requires the conning officer to decide when the point of laying the depth charges is reached and to spread them in a properly spaced pattern by launching the several components at predetermined distances as the ship proceeds. If the ship could proceed directly from the point of departure to the point of attack at a constant known speed, he could execute this final stage of the attack by the aid of time measurements alone. But the approach path includes an arc of the turning circle, and, to restrict the movements of the target, is often traversed at an accelerating speed. The difficulties introduced by these conditions have led to the development of various aids such as the Attack Meter, the Chemical Recorder and several other devices that are in various stages of completion.

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51. The Direct Attack procedure locates the bomb pattern accurately under all speed conditions by reception of echoes directed vertically from the target. It calls for no computations either directly or through gadgetry and thereby confines the part played by the conning officer to directing his course in accordance with the sound bearings and to pressing a key that closes the firing circuits of the bomb projectors.

52. Numerous statistical reports on the percentage of kills per contact show that comparatively few officers have the extensive training and experience required to coordinate to best advantage all the elements entering into the present Indirect Attack procedure. Moreover, the growing seriousness of the U-boat menace permits neither time nor opportunity for gaining such experience. Therefore, the need for a new or modified anti-submarine attack procedure that can be effectively executed with a minimum of training and experience is obvious.

IV. SUMMARY AND CONCLUSIONS

53. The aforesaid may be summarized briefly as follows:

(a) Control of the U-boat menace is determined by the product of two factors - the frequency of sound contact and the percent of the contacts that result in kills - and hence the control cannot be made effective so long as either of these factors approximates zero.

(b) The frequency of contact factor under our coastwise shipping conditions will continue to be too small so long as it is determined by the patrol ships alone and unaided. It might be raised to thoroughly practical values through cooperation with the aircraft patrol.

(c) Such cooperation would require that both blimps and patrol planes be equipped with underwater sound detectors by which they can hold sound contact with the U-boats they force to submerge until a patrol ship can arrive and take over the attack.

(d) Full effectiveness of such a program calls for the experimental development of an anti-submarine plane or glider.

(e) The present low value of the percent of kills factor is an inherent result of permitting the target a potential escape area that is large with respect to that of any practical bomb pattern. This inherent weakness of the present Indirect Attack procedure cannot be overcome through improving the present sound detecting equipment.

(f) The potential escape area becomes a minimum when the bomb pattern is centered about an attack point located directly over the target. Its area then can be kept within the

limits of the bomb pattern through the use of high-speed contact or proximity-fused bombs. Utilization of such an attack point requires that the attack approach shall be directed across the target.

(g) Such an approach can be directed and the attack point can be indicated at the instant of crossing the target by the present QB or QC equipments by mounting the projector so that it can be measurably tilted within the angular range from horizontal to vertically downward. This modification calls for no extensive construction and installation program.

(h) The training and experience required to execute such an approach - The Direct Attack - is relatively small.

(i) The percent of kills factor can definitely be increased by the development of an anti-submarine ship.

54. In the light of this summation we find a clear and convincing answer to the subject question - "How can our present unsatisfactory control of the U-boat menace be improved?" The answer is - "Bring the patrol ships into more frequent sound contact with the U-boats through the use of under-water sound detectors installed on the various units of the aircraft patrol and increase the percent of the patrol ship attacks that result in kills by providing these ships with the required materiel and personnel for executing the Direct Attack."

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